CALIFORNIA DEPARTMENT OF FOOD AND AGRICULTURE
FERTILIZER RESEARCH AND EDUCATION PROGRAM (FREP)

FINAL REPORT

Project Title: ***Increasing Yield of the 'Hass' Avocado by Adding P and K to Properly Timed Soil N Applications***

CDFA-FREP Contract No. 03-0653

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Statement of Objective: Results obtained from two previous CDFA-FREP funded research projects established that the time of N application to the soil was more important than the amount of N with regard to yield and fruit size of the 'Hass' avocado in California. Application of N in July and August (40 lbs. total N per acre per year) achieved an equal or greater total yield and yield of commercially valuable large size fruit (packing carton sizes 60+48+40, i.e., fruit weighing 178-325 g/fruit) for the 4 years of the study than multiple N treatments supplying 68% more N. The research was conducted in orchards with optimal nutrition based on standard leaf analysis and located in two climatically and edaphically different avocado-growing areas of California to determine whether strategies work across avocado-producing areas of the state. With identification of the proper time to apply N fertilizer, the next logical question was whether a greater response to N soil applications would be obtained if P and K were supplied simultaneously. Due to its immobility, P is commonly limiting. K runs a close second due to its high mobility and loss by leaching. In addition, avocado trees have a high demand for K because avocado fruit are rich in K, having more K/g fresh wt. edible fruit than bananas! This project tested the following hypothesis: low available soil P or K at key stages in tree phenology will diminish the tree's response to properly timed soil-applied N.

Project Objectives: The objectives of the research were: (1) to quantify the effects of properly timed soil-applied N vs. N supplemented with P and K on yield, fruit size and alternate bearing index in a commercial 'Hass' orchard with optimal nutrition based on leaf analysis, and (2) to disseminate the results of the research to the avocado growers of California.

Executive Summary: The fertilizer strategies significantly affected 3-year cumulative total yield as both kilograms (P = 0.0035) and number of fruit (P = 0.0111) per tree. Trees receiving 1x NPK in July and August produced a significantly greater 3-year cumulative total yield (in kilograms and number of fruit per tree) than trees receiving 2x N in November, 2x NPK in November, 2x NPK in April and BMP NPK. All other treatments resulted in intermediate 3-year cumulative total yields that were not significantly different from any other treatment. Trees

receiving 1x NPK in July and August and 2x N in April had significantly higher yields of commercially valuable large size fruit in the combined pool of packing carton sizes 60+48+40 as both kilograms (P = 0.0109) and number of fruit (P = 0.0105) per tree than trees receiving 2x NPK in November and BMP NPK. Yields for all other treatments were intermediate and not significantly different from any other treatment. In comparison to trees receiving only 1x N in July and August, supplementing N in this treatment with P and K had a consistent beneficial, though not statistically significant, effect on total yield and yield of commercially valuable large size fruit (combined pool of packing carton sizes 60+48+40; fruit weighing 178-325 g/fruit). Trees treated with 1x NPK in July and August produced total yields and yields of large size fruit (178-325 g/fruit) equal to or greater than trees receiving all other treatments, including the BMP N (control) or BMP NPK treatments. Note that trees receiving 1x NPK in July and August received 50% less N than trees in all other treatments and 50% less N P K than the other NPK treatments.

By September 2006, leaf analyses revealed that the BMP N (control) treatment had the highest leaf N concentration and trees receiving 1x N in July and August the lowest. Trees receiving BMP NPK or 1x NPK in July and August had leaf N concentrations that were significantly lower than the BMP N (control) but intermediate to and not significantly different from any other treatment. Leaf P concentration was not affected by fertilization. Trees receiving 1x NPK in July and August had the highest leaf K concentration, which was higher than all other treatments except BMP NPK and 2x NPK in April. Leaf NPK concentrations for trees in all treatments were in the middle to upper end of the optimal range. Despite receiving 50% less N or NPK, trees receiving 1x N or 1x NPK in July and August had increased leaf N or NPK concentrations, respectively, at the end of year 3.

Averaged over the 3 years of the experiment, fertilizer treatment had a significant effect only on the fruit quality parameter vascularization, the presence of vascular bundles and associated fibers in the flesh (P = 0.0405). The lowest amount of vascularization was in fruit from trees receiving 1x NPK in July and August and 2x NPK in April.

Conclusion: The results of this study confirmed that application of N in July and August at a significantly reduced rate (40-50 lbs. N/acre compared to 125-150 lbs. N/acre) results in total yields and yields of commercially valuable large size fruit that were equal to or greater than strategies with more frequent N applications supplying 50% to 68% more N fertilizer annually. July and August correspond to the following phenological and physiological events: July – period of "June" drop for the current crop (Garner, 2004), rapid N and K uptake by mature fruit from the previous spring bloom (Rosecrance and Lovatt, unpublished data), and development of the summer vegetative flush (Salazar-García et al., 1998) and August – period of exponential increase in fruit size for the current crop and abscission of mature fruit (Garner, 2004) and inflorescence initiation for next year's crop (Salazar-García et al., 1998). Supplying 1x NPK in July and August had a consistent beneficial, though not significant, effect on total yield and yield of commercially valuable large size fruit (combined pool of packing carton sizes 60+48+40; fruit weighing 178-325 g/fruit) compared to trees receiving only N in July and August, and resulted in total yields and yields of large size fruit (178-325 g/fruit) equal to or greater than trees receiving 50% more N or NPK, including the BMP N (control) or BMP NPK treatment. Based on 7 years of yield data for 1x N in July and August and 3 years for 1x NPK in July and August, these fertilization strategies are cost-effective in sustaining high total yields and yields of large size fruit while protecting the environment and recommended for use with regular monitoring by leaf analysis.

Work Description: To meet objective (1) the two fertilizer treatments were applied at the following times (treatments): July-August; November; April; and August, November, April and July (control) (a total of 8 treatments) (Table 1). These application times correspond to the following key stages of 'Hass' avocado tree phenology: July – period of rapid cell division and significant increase in fruit size, August – inflorescence initiation; November – end of the fall vegetative flush and beginning of flower initiation; and April – anthesis, fruit set and initiation of the spring vegetative flush. The N rates and application times are based on the results of Lovatt (2001) and the CAC and CDFA-FREP projects reported. P and K fertilizer were applied to half the trees treated with N (20 trees per treatment). All trees received 1x rate of P and K simultaneously with the N application. K_2HPO_4 and KNO_3 were used to provide the required amounts of P and K. The amount of ammonium nitrate-N applied was reduced by the amount of N supplied as KNO_3.

The experimental design was a randomized complete block with 20 individual tree replicates per treatment (8 treatments) to insure that any differences in yield observed could be evaluated as statistically significant at the 5% level. The orchard was located in Somis, Calif. The trees were 24-year-old 'Hass' on Duke 7.

To determine tree nutrient status, 40 spring flush leaves from nonfruiting terminals were collected at chest height around each data tree in September of each year. The leaves were immediately stored on ice, taken to UCR, washed thoroughly, oven-dried at 60 ºC and ground to pass through a 40-mesh screen. Leaf nutrient concentrations were determined by atomic absorption spectrometry and inductively coupled plasma atomic emission spectrometry by the Division of Agriculture and Natural Resources Analytical Laboratory at UC Davis.

Harvest data included total kg fruit/tree. The weight of 100 randomly selected individual fruit/tree were used to calculate packout (fruit size distribution)/tree. Two fruit per tree were evaluated for the length of time to ripen, peel color at maturity, and internal fruit quality (seed germination, vascularization, discoloration, and decay). Fruit quality parameters were visually determined using a scale from 0 (none) to 4 (extensive, present in all four quarters of the fruit). All data were statistically analyzed using the General Linear Model procedures of SAS. ANOVA was used to test for treatment effects on leaf nutrient concentrations, yield, fruit size, and fruit quality parameters. Means were separated using Duncan's multiple range test at $P \leq 0.05$. Treatment effects on cumulative yield and on alternate bearing index [ABI = (year 1 yield – year 2 yield) ÷ (year 1 yield + year 2 yield)] were determined by ANOVA. Treatment effects across years were determined by repeated measures analysis with year as the repeated measures factor. A cost/benefit analysis for each treatment was calculated.

Evaluation of the progress of this research is straightforward since every activity is carried out at a specified time.

YEAR 1 – TASK 1: The objectives of the proposed research are: (1) to quantify the effects of properly timed soil-applied: N vs. N supplemented with P and K on yield, fruit size and alternate bearing index in a commercial 'Hass' orchard with optimal nutrition by leaf analysis and (2) disseminate the results of the research to the avocado growers of California.

Month of initiation: 2/04 Month of completion 1/05

Subtask 1.1: Lay out the experiment, select trees of similar size, crop load and health, and label data trees.

Subtask 1.1 will be initiated and completed in February 2004.

Subtask 1.2: Monitor tree phenology and apply fertilizer treatments at the appropriate time.

Subtask 1.2 will be initiated in April 2004 and completed in November 2004.

Subtask 1.3: Harvest mature crop and statistically analyze the yield data to confirm that selected data trees had uniform yields at the initiation of the research and the experiment is blocked effectively.

Subtask 1.3 will be initiated in August 2004 and completed in September 2004.

Subtask 1.4: Collect and process leaves for leaf analysis. Send leaf samples to Division of Agriculture and Natural Resources Analytical Laboratory at UC Davis. Statistically analyze the results.

Subtask 1.4 will be initiated in September 2004 and completed in December 2004.

Subtask 1.5: Prepare and send annual report to FREP.

Subtask 1.5 will be initiated in December 2004 and completed in January 2005.

YEAR 2 – TASK 2: The objectives of the proposed research are: (1) to quantify the effects of properly timed soil-applied: N vs. N supplemented with P and K on yield, fruit size and alternate bearing index in a commercial 'Hass' orchard with optimal nutrition by leaf analysis and (2) disseminate the results of the research to the avocado growers of California.

Month of initiation: 2/05 Month of completion 1/06

Subtask 2.1: Monitor tree phenology and apply fertilizer treatments at the appropriate time.

Subtask 2.1 will be initiated in April 2005 and completed in November 2005.

Subtask 2.2: Harvest mature crop and statistically analyze the yield data.

Subtask 2.2 will be initiated in August 2005 and completed in September 2005.

Subtask 2.3: Collect and process leaves for leaf analysis. Send leaf samples to Division of Agriculture and Natural Resources Analytical Laboratory at UC Davis. Statistically analyze the results.

Subtask 2.3 will be initiated in September 2005 and completed in December 2005.

Subtask 2.4: Present the results of the first crop year at the Annual FREP Conference.

Subtask 2.4 will be initiated and completed in November 2005.

Subtask 2.5: Prepare and send annual report to FREP.

Subtask 2.5 will be initiated and completed in December 2005 and completed in January 2006.

YEAR 3 – TASK 3: The objectives of the proposed research are: (1) to quantify the effects of properly timed soil-applied: N vs. N supplemented with P and K on yield, fruit size and alternate bearing index in a commercial 'Hass' orchard with optimal nutrition by leaf analysis and (2) disseminate the results of the research to the avocado growers of California.

Month of initiation: 2/06 **Month of completion 1/07**

Subtask 3.1: Monitor tree phenology and apply fertilizer treatments at the appropriate time.

Subtask 3.1 will be initiated in April 2006 and completed in August 2006.

Subtask 3.2: Harvest mature crop and statistically analyze the yield data.

Subtask 3.2 will be initiated in August 2006 and completed in September 2006.

Subtask 3.3: Collect and process leaves for leaf analysis. Send leaf samples to Division of Agriculture and Natural Resources Analytical Laboratory at UC Davis. Statistically analyze the results.

Subtask 3.3 will be initiated in September 2006 and completed in December 2006.

Subtask 3.4: Present the results of the second crop year at the CAC-UCR Annual Avocado Grower's Symposium and Annual FREP Conference.

Subtask 3.4 will be initiated in October 2005 and completed in November 2005.

Subtask 3.5: Prepare and send final report to FREP. Write and submit manuscripts to *Journal of the American Society for Horticultural Science* and *AvoResearch*. Disseminate the results of the research to California avocado growers by requesting to speak at CAC grower education seminars and seminars hosted by farm advisors and packing houses.

Subtask 3.5 will be initiated and completed in December 2006 and completed in January 2007.

Results: *Leaf N concentration.* When leaves were collected for analysis in Sept. 2004, the trees had only been under treatment for half a year, so trees had not received their total annual N or NPK, except trees receiving 1x N or NPK in July and August only. In 2004, September leaf N concentrations were higher than the 2.1% recommended by the California Avocado Commission for the 'Hass' avocado. By Sept. 2004, trees receiving 2x NPK in April had the highest leaf N concentration, which was significantly greater than leaves from trees receiving 1x N or NPK in July and August and the BMP NPK treatment, but not significantly different from leaves of trees receiving 2x N in April, BMP N or 2x N or NPK in November, which had intermediate leaf N concentrations (Table 2). In 2005, leaf N concentrations for trees in all treatments were lower and closer to the recommended 2.1% N. Trees receiving 2x NPK in April again had the highest leaf N concentration obtained, but it was not significantly different from that of trees receiving BMP N, 2x N in April, or 2x N in November, all of which had leaf N concentrations significantly greater than trees receiving 2x NPK in November. Trees receiving 1x N or NPK in July and August or BMP NPK had intermediate concentrations of leaf N that were not significantly different from leaf N concentrations for all other treatments (Table 2). By Sept. 2006, leaf analyses revealed that the BMP N (control) treatment had the highest leaf N concentration and trees receiving 1x N in July and August the lowest (Table 2). Trees receiving BMP NPK or 1x NPK in July and August had leaf N concentrations that were significantly lower than the BMP N (control) but intermediate to and not significantly different from any other treatments. Trees receiving 50% less N or NPK still showed an increase in leaf N concentrations by year 3. For all 3 years of the study, leaf N concentrations were greater than the 2.1% recommend by the California Avocado Commission.

Leaf P concentration. Leaf P in 2004 tended to be lower than in 2005, but within the preferred range presently in use. In addition, the 2004 leaf P concentrations exhibited more variation than in 2005 (Table 2), but keep in mind that only trees receiving 1x N or NPK in July and August had received their total annual N or NPK treatment. In 2004, trees receiving 1x NPK in July and August had greater leaf P concentrations than trees receiving 1x N in July and August, 2x NPK in November, 2x N in April and BMP NPK. Trees in the BMP N treatment had leaf P concentrations that were intermediate but still significantly greater than trees in the BMP NPK treatment. Trees receiving 2x N in November and 2x NPK in April had leaf P concentrations that were intermediate and not significantly different from any other treatment. In 2005, September leaf P concentrations were optimal for all treatments. Trees receiving 2x N in November had the highest leaf P concentration, which was significantly greater than trees receiving 1x N in July and August but only at $P = 0.1078$ (Table 2). Leaf P concentrations for all other treatments were intermediate and not significantly different from all other treatments. In 2006, leaf P concentration was not affected by fertilization treatment (Table 2). Trees receiving 50% less P still showed an increase in leaf P concentration by September of year 3 of the study. For all years of the study, leaf P concentrations for all treatments were well within the optimal range for P presently in use.

Leaf K concentration. In 2004, there were no significant treatment effects on leaf K concentration (Table 2). Values ranged from 1.19% to 1.33%, which were within the current optimal range. By 2005, leaf K concentration was significantly affected by the fertilizer treatments (Table 2). Trees receiving 2x N in November had the highest leaf K concentration and it was significantly greater than leaf K for trees in all other treatments except trees receiving 1x NPK in July and August. Trees receiving 1x NPK in July and August had greater leaf K concentrations than trees receiving 1x N in July and August, but also trees in all other NPK treatments, i.e., 2x NPK in November, 2x NPK in April and BMP NPK. By Sept. 2006, trees receiving 1x NPK in July and August had the highest leaf K concentration, which was higher than all other treatments except BMP NPK and 2x NPK in April (Table 2). Leaf K for trees in all treatments was in the middle to upper end of the optimal range presently used for avocado. Trees receiving 50% less K still showed an increase in leaf K concentration over the 3 years of the study.

Averaged over the 3 years of the experiment, fertilization strategy had a significant effect on leaf N (P = 0.0029), P (P = 0.0246), and K (P = 0.0113) concentrations (Table 3). Leaf N concentrations were highest for trees receiving 2x NPK in April and the BMP N (control) treatment and significantly greater than trees receiving 1x N in July and August, 1x NPK in July and August, 2x NPK in November and the BMP NPK treatment (Table 3). Trees receiving 2x N in November and 2x N in April had intermediate leaf N concentrations that were not significantly different from those of all other treatments. Averaged over the 3 years of the study, leaf P concentration was highest in trees receiving the BMP N (control) treatment and significantly greater than leaves from trees receiving 2x NPK in November, 1x N in July and August, and the BMP NPK treatment (Table 3). Leaf P for other treatments was intermediate and not significantly different from other treatments. Leaf K concentrations averaged over the 3 years were highest in leaves from trees receiving1x NPK in July and August and significantly greater than leaf K concentrations for trees in all other treatments, except trees receiving 2x N in November (Table 3).

Averaged across the 3 years of the experiment, year had a significant effect on leaf N ($P <$ 0.0001), P ($P <$ 0.0001), and K ($P <$ 0.0001) (Table 3). Leaf NPK concentrations were significantly higher in 2006 compared to all prior years. Leaf N was significantly lower in 2005, the off-crop year, than in 2006 and 2004. Leaf P was significantly lower in 2004, the on-crop year, than in 2005 and 2006. Leaf K in 2004 and 2005 were the same and significantly lower than in 2006.

Relationships between leaf nutrient concentrations and yield parameters. Leaf N was not related to total yield or fruit size in either year of the study. This is consistent with results obtained in all other N fertilization studies with the ‘Hass’ avocado (Lovatt and Witney, 2001). Leaf P concentration in Sept. 2004 was positively and significantly ($P <$ 0.0001) related to the yield of large size fruit (combined pool of packing carton sizes 60+48+40) in the harvest of 2004, the on-crop year. Leaf P concentration explained 22% of the variation in the yield of large size fruit. Sept. 2005 leaf P concentrations were not significantly related to any yield parameter. Leaf K concentration in Sept. 2004 and 2005 was not related to any yield parameter. Leaf N, P and K were not related to any yield parameter in 2006.

Yield 2004. Funding for this project began in Feb. 2004 with the first treatments applied in Apr. 2004. Yield data for a size pick of July 2004 [only large size fruit (≥ packing carton size 60) were harvested] were combined with the final strip pick in Sept. 2004. Thus, the control trees and trees receiving N or NPK in November had received only part or none of the fertilizer treatments, respectively.

Trees receiving 1x NPK (25, 3.75 and 22.5 lbs. NPK/acre, respectively) in July and again in August yielded significantly more large size fruit (combined pool of packing carton sizes 60+48+40, i.e., fruit weighing 178-325 g, and packing carton sizes ≥ 60, i.e., fruit weighing ≥ 173) per tree ($P \leq$ 0.10) and had numerically, but not significantly, more total yield per tree compared to trees receiving only 1x N in July and August, trees in the BMP for NPK treatment, and trees receiving a double dose of NPK (2x NPK) in November. Supplying P and K with N in the other treatments had no significant effect on total yield or yield of large size fruit at the end of this first partial year of the experiment. Thus, the experiment is blocked appropriately.

Only trees receiving 1x N or NPK in April or in July and again in August received the full treatment in this short period before the final harvest. In a pair-wise comparison of trees receiving N versus NPK in April, there were no differences in yield between the fertilizer treatments. However, in a pair-wise comparison of trees receiving N versus NPK in July and again in August, the trees receiving NPK had a significantly greater total yield as both kg and number of fruit per tree ($P \leq 0.03$) and significantly greater yield of fruit of the following packing carton sizes in both kg and number per tree: 60 ($P \leq 0.08$), 48 ($P \leq 0.05$), 40 ($P \leq 0.08$), 36 ($P \leq 0.03$), 32 ($P \leq 0.07$), and the combined pool of ≥ 60 ($P \leq 0.004$).

Fertilization treatments had no effect on the length of time it took for fruit to ripen after harvest, peel color at maturity, seed size, seed germination at maturity, or vascularization or discoloration of the mature fruit flesh. The trees receiving the BMP NPK (control) treatment through September had significantly more internal flesh decay, especially at the stem end, than all other trees receiving full or partial treatments ($P \leq 0.10$).

Yield 2005. The orchard is alternate bearing and the yield for 2005 was the off crop. In 2005, due to alternate bearing, trees receiving 1x NPK in July and again in August had statistically less kilograms and number of fruit per tree than all other treatments ($P = 0.0339$). Trees in all other treatments had yields that were not significantly different from each other.

In 2005, trees receiving 2x N in April or 2x N November produced significantly more fruit of packing carton size 60 (as both kilograms and number per tree) than trees receiving 1x NPK in July and again in August ($P = 0.0753$). Yields of fruit of packing carton size 60 for trees in all other treatments were intermediate to and not significantly different from these two treatments. Trees receiving 2x N in April also produced significantly more fruit of packing carton size 48 (as both kilograms and number per tree) than trees receiving 1x NPK in July and again in August and the BMP N trees ($P = 0.0232$). Trees in all treatments produced more fruit of packing carton size 48 (as both kilograms and number per tree) than the trees receiving 1x NPK in July and again in August, with the yields of fruit of packing carton size 48 for these treatments being intermediate to and not significantly different from trees receiving 2x N in April or BMP N. The yield of fruit in the combined pool of 60+48+40 was the same for all N treatments except 1x NPK in July and again in August. Trees in this treatment produced significantly more fruit in this size category in 2004 and, thus, due to alternate bearing, significantly less in 2005 ($P = 0.0112$). Trees in the BMP N treatment produced the second highest yield of commercially valuable large size fruit in the combined pool of 60+48+40 in 2004 and the next fewest fruit of packing carton sizes 60+48+40 in 2005. The number of small size fruit of packing carton sizes 70 or 84 or the combined pool of fruit of packing carton sizes 70+84 was not affected by any fertilization strategy.

For the 2005 yield, pair-wise comparisons of trees receiving N versus NPK in April, N versus NPK in November or BMP N versus NPK indicated no differences in total yield or fruit size between the paired fertilizer treatments (data not shown). However, in a pair-wise comparison of trees receiving N versus NPK in July and again in August, the trees receiving NPK had a significantly lower total yield as both kg and number of fruit per tree ($P = 0.0067$) and significantly lower yield of fruit of the following packing carton sizes in both kg and number per tree: 60 ($P = 0.0169$), 48 ($P = 0.0142$), and the combined pool of fruit ≥ 60 ($P = 0.0121$). This result was the exact opposite from 2004 when trees in this treatment produced significantly more fruit in these size categories and reflects the effects of alternate bearing.

Fertilization treatments had no effect on the length of time it took for fruit to ripen after harvest, vascularization or discoloration of the mature fruit flesh or decay ($P \leq 0.05$). Trees receiving the 2x NPK in April ripened approximately 2 days faster than fruit from trees receiving 1x N in July and August and trees receiving BMP NPK ($P = 0.0914$). Trees receiving the 2x

NPK in April, 1x NPK in July and August, and BMP N had less vascularization of the flesh of the avocado fruit than trees receiving 1x N in July and August (P = 0.0654). A pair-wise comparison of each N versus NPK treatment revealed differences in fruit quality for trees receiving N or NPK in July and August. The addition of P and K to this N timing reduced the vascularization of the fruit flesh (P = 0.0655), but increased the discoloration of the flesh (P = 0.0766).

Yield 2006. Fertilizer treatment had a statistically significant effect on total yield as both kilograms (P = 0.0146) and number of fruit (P = 0.0345) per tree. The best treatment was 1x NPK in July and August only. It was significantly better than all other treatments except 1x N in July and August only and BMP N (control), which were intermediate to and not significantly different from any other treatment. Fertilizer strategies also significantly affected the yield of large size fruit of packing carton sizes 60 (P = 0.0028), 48 (P = 0.0044) and 40 (P = 0.0996) and the yield of fruit in the combined pool of fruit of packing carton sizes 60+48+40 (P = 0.0015) as kilograms fruit per tree. In all cases, the best treatment was 1x NPK in July and August only. The same was true when yield was determined as number of fruit per tree. Thus, 1x NPK applied in July and August not only increased fruit retention, but also increased fruit growth. Comparison of the BMP N treatment with the BMP NPK treatment provided clear evidence that supplying P and K this frequently at the rate used in this study had a negative effect on yield.

There were no fertilizer treatment effects on the number of days required for fruit to ripen after harvest, fruit length, fruit width or seed size, but treatments influenced the width of the flesh (edible portion of the fruit) (P = 0.0046). Trees treated with BMP NPK produced fruit with significantly wider flesh than fruit from trees treated with 1x N in July and August, 2x N in April and BMP N (control). Fruit from all other treatments had flesh that was intermediate in width and not significantly different from any other treatment. Fertilizer strategies had no significant effect on peel color, flesh quality, or seed germination.

Three-year average yield. When averaged across the 3 years of the study, fertilizer strategies had significant effects on total yield as kilograms (P = 0.0020) and number of fruit (P = 0.0060) per tree (Tables 4 and 5). Trees treated with 1x NPK in July and August had a significantly greater 3-year average total yield in kilograms per tree than trees treated with 2x N in November, 2x NPK in November, 2x NPK in April and BMP NPK. Trees receiving other treatments had 3-year average total yields that were intermediate and not significantly different from any other treatment (Table 4). The BMP N (control) treatment resulted in a 3-year average yield of small fruit of packing carton size 70 that was significantly greater as both kilograms and number of fruit per tree than trees receiving 2x N in November, 2x NPK in November, 2x NPK in April or BMP NPK (P = 0.0221) (Tables 4 and 5). Trees receiving 1x NPK in July and August or BMP N (control) had a significantly greater 3-year average yield of large size fruit of packing carton size 60 as both kilograms (P = 0.0133) and number of fruit (P = 0.0133) per tree compared to trees receiving 2x NPK in November and BMP NPK (Tables 4 and 5). Trees receiving 1x NPK in July and August or 2x N in April had the highest 3-year average yields of fruit in the combined pool of fruit of packing carton sizes 60+48+40 as both kilograms (P = 0.0223) and number of fruit (P = 0.0170) per tree (Tables 4 and 5). All other treatments produced yields that were intermediate and not significantly different from any other treatment. Year had a statistically significant effect on every yield parameter except the kilograms and number of fruit of packing carton size 60 (Tables 4 and 5). Year 1 was an on-crop year followed by two off-crop years. Note that the first off-crop was characterized by the production of large size fruit at the expense of small size fruit. In contrast, the subsequent off-crop was comprised predominantly of small size fruit with few large size fruit (Tables 4 and 5). Treatment by year interactions affected the yield (as both kilograms and number of fruit per tree) of fruit of packing carton sizes 60 ($P = 0.0385$) and 48 ($P = 0.0143$) and yield of fruit in the combined pool of packing carton sizes 60+48+40 ($P = 0.0143$) (Tables 4 and 5).

Three-year cumulative yield. The fertilizer strategies significantly affected 3-year cumulative total yield as both kilograms ($P = 0.0035$) and number of fruit ($P = 0.0111$) per tree (Tables 6 and 7). Trees receiving 1x NPK in July and August produced a significantly greater 3-year cumulative total yield (in kilograms and number of fruit per tree) than trees receiving 2x N in November, 2x NPK in November, 2x NPK in April and BMP NPK. All other treatments resulted in intermediate 3-year cumulative total yields that were not significantly different from any other treatment (Tables 6 and 7). Trees receiving 1x NPK in July and August or BMP N (control) had marginally greater 3-year cumulative yields of fruit of packing carton size 60 (as kilograms and number of fruit per tree) than trees receiving BMP NPK, but not any other treatment ($P = 0.0661$) (Tables 6 and 7). Trees receiving 1x NPK in July and August and 2x N in April had significantly higher yields of fruit in the combined pool of packing carton sizes 60+48+40 as both kilograms ($P = 0.0109$) and number of fruit ($P = 0.0105$) per tree than trees receiving 2x NPK in November and BMP NPK (Tables 6 and 7). Yields for all other treatments were intermediate and not significantly different from any other treatment.

Three-year average fruit quality. Averaged over the 3 years of the experiment, fertilizer treatment had a significant effect only on vascularization, the presence of vascular bundles and associated fibers in the flesh ($P = 0.0405$) (Table 8). The lowest amount of vascularization was in fruit from trees receiving 1x NPK in July and August and 2x NPK in April. Year was a significant factor influencing the number of days required for fruit to ripen, vascularization, flesh discoloration and decay. There was, however, no significant treatment by year interactions (Table 8).

Alternate bearing. The alternate bearing index (ABI) for 2004-2005 ranged from 0.54 to 0.66 (Table 9). For 2005-2006, alternate bearing was more severe, i.e., ABIs ranged from 0.62 to 0.70 (Table 9). The fertilizer treatments had no significant effect on alternate bearing (Table 9).

Cost-benefit analysis. Fertilizer strategies had no significant effect on total income at the end of the 3 years of the study (Table 10). However, the highest income was generated by 1x NPK in July and August > 1x N in July and August > BMP N (control) > 2x NPK in April > 2x N in April > 2x NPK in November > 2x N in November > BMP NPK. Considering that the treatments supplying 1x NPK in July and August or 1x N in July and August required application of 50% less fertilizer than all other treatments, these treatments had the lowest cost and maximum benefit.

Discussion and Conclusions: The results of this study confirmed that application of N in July and August at a significantly reduced rate (40-50 lbs. N/acre compared to 125-150 lbs. N/acre) results in total yields and yields of commercially valuable large size fruit that are equal to or greater than strategies with more frequent N applications supplying 50% to 68% more N fertilizer annually. July and August correspond to the following phenological and physiological events: July – period of "June" drop for the current crop (Garner, 2004), rapid N and K uptake by mature fruit from the previous spring bloom (Rosecrance and Lovatt, unpublished data), and development of the summer vegetative flush (Salazar-García et al., 1998) and August – period of exponential increase in fruit size for the current crop and abscission of mature fruit (Garner, 2004), and inflorescence initiation for next year's crop (Salazar-García et al., 1998). Supplying 1x NPK in July and August had a consistent beneficial, though not significant, effect on total yield and yield of commercially valuable large size fruit (combined pool of packing carton sizes 60+48+40; fruit weighing 178-325 g/fruit) compared to trees receiving only N in July and August, and resulted in total yields and yields of large size fruit (178-325 g/fruit) equal to or greater than trees receiving 50% more N or NPK, including the BMP N (control) or BMP NPK treatment. Based on 7 years of yield data with 1x N in July and August and 3 years with 1x NPK in July and August, these fertilization strategies are cost-effective in sustaining high total yields and yields of large size fruit while protecting the environment and are recommended, with regular monitoring by leaf analysis.

The results of the research demonstrated that the time N was applied to the soil in relationship to tree phenology was more important than the amount of N applied (at the rates used in this research) and more important than whether P and K were also supplied (at the rates used in this research).

Dissemination of project results (Objective 2): I was invited to speak about my avocado nitrogen research to avocado growers of California on Saturday, Oct. 29, 2004, at the University of California, Riverside (UCR), at the annual California Avocado Research Symposium. I presented an overview of results of our research on nutritional management of avocados and I spoke specifically about this project to keep the growers apprised of our research since this project is not one funded by the California Avocado Commission (CAC). There is international interest in this and previous research funded by the CDFA-FREP program on nitrogen nutrition of the avocado. I was invited by the New Zealand-Australian Avocado Growers Association to speak at their next meeting in Sept. 2005 in Taraunga, NZ. I was unable to attend, but Guy Witney, Director of Industry Affairs for CAC, presented a summary I prepared of the results of this research. I presented two posters on our FREP sponsored research to avocado growers of California at the annual Avocado Research Symposium sponsored by UCR and CAC on Saturday, Oct. 29, 2005, at UCR. One poster presented the results of our second completed 4-year study on proper timing of nitrogen for 'Hass' avocado production (Salvo and Lovatt, Development of Nitrogen Best Management Practices for the 'Hass' Avocado) and the other was on nutrient replacement fertilization for the 'Hass' avocado (Rosecrance, Faber and Lovatt, Seasonal Patterns of Nutrient Uptake and Partitioning as a Function of the On- or Off-crop Status of the 'Hass' Avocado). I presented posters on these projects to make the growers aware of this research. Since the research was not funded by CAC, an oral presentation was not possible. Posters made it possible for growers to see the results of our FREP-funded research. There were 200+ individuals in attendance and I was able to discuss the posters with a large number of people.

I presented two talks on the results of the CDFA-funded research project conducted by Rosecrance, Faber and Lovatt. The first talk, entitled "Seasonal Patterns of Nutrient Uptake and Partitioning as a Function of the On- or Off-crop Status of the 'Hass' Avocado," was given at the 2005 Coastal Nutrient Conference sponsored by the Western Plant Health Association, on Aug. 4, 2005, at the Embassy Suites, San Luis Obispo, CA. A very similar talk, "Seasonal Patterns of Nutrient Uptake and Partitioning as a Function of Crop Load of the 'Hass' Avocado and Rate of Fertilization" was given at the Annual FREP Symposium, Nov. 29, 2005, at the National Steinbeck Center, Salinas, CA. Both talks were invited and in each case this topic was requested. Both talks included an update on our research into the proper timing of soil applied N vs. NPK for the 'Hass' avocado.

In 2006, I attended the annual meeting of the South Africa Avocado Growers Association (SAAGA) and presented the posters I presented at the last UCR-CAC Avocado Research

Symposium at the SAAGA Conference. I also was invited to give a presentation discussing our current understanding of avocado tree nutrition, the timing of fertilizer applications, and why it its important to use leaf and soil analyses for production, fruit quality and tree health at grower seminars hosted jointly by the University of California Cooperative Extension, CAC and the California Avocado Society (CAS) in San Luis Obispo, Ventura and Escondido, CA. I was told that talks were well received and I was invited back to provide the most recent results of our research at the same three meetings in 2007. I also presented the results of this research at the 2006 CDFA-FREP Annual meeting in Monterey, CA, entitled "Increasing yield of the 'Hass' avocado by adding P and K to properly timed soil-N applications."

Project Evaluation: Evaluating the progress of this research was straightforward because every activity was carried out at the specified time. All tasks and subtasks were completed at the time specified in the proposal. The results of the research showed that ***the time N was applied to the soil in relationship to tree phenology was more important than the amount of N applied (at the rates used in this research) and more important than whether P and K were also supplied (at the rates used in this research).***

Acknowledgement. I would like to express my sincere appreciation to Mr. John Grether. Without special individuals like Mr. Grether, who make their orchards available for the type of research reported herein, FREP-funded projects would not be possible. This is Mr. Grether's second such project with me and I am extremely grateful.

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Table 1. N, P and K fertilization strategies.

Treatment	Month of application														
	April			July			August			November			Total		
	N[z]	P	K	N[z]	P	K	N[z]	P	K	N[z]	P	K	N[z]	P	K
	lbs./acre														
1x N in July +August	–	–	–	25	–	–	25	–	–	–	–	–	50	–	–
1x NPK in July + August	–	–	–	25	3.75	22.5	25	3.75	22.5	–	–	–	50	7.5	45
2x N in November	16.7	–	–	16.7	–	–	16.7	–	–	50	–	–	100	–	–
2x NPK in November	16.7	2.5	15	16.7	2.5	15	16.7	2.5	15	50	7.5	45	100	15	90
2x N in April	50	–	–	16.7	–	–	16.7	–	–	16.7	–	–	100	–	–
2x NPK in April	50	7.5	45	16.7	2.5	15	16.7	2.5	15	16.7	2.5	15	100	15	90
BMP N (Control) (1x N in July, Aug., Nov. + Apr.)	25	–	–	25	–	–	25	–	–	25	–	–	100	–	–
BMP NPK (1x NPK in July, Aug., Nov. + Apr.)	25	3.75	22.5	25	3.75	22.5	25	3.75	22.5	25	3.75	22.5	100	15	90

[z] Nitrogen applied as ammonium nitrate.

Table 2. Effect of soil-applied N or NPK fertilizer on leaf total N, P and K (expressed as % dry wt.) of the 'Hass' avocado.

	2004			2005			2006		
Treatment	N	P	K	N	P	K	N	P	K
1x N in July +August	2.31 b[z]	0.15 bc	1.23	2.13 ab	0.16 b	1.21 c	2.45 c	0.18	1.30 b
1x NPK in July + August	2.28 b	0.16 a	1.31	2.17 ab	0.16 ab	1.32 ab	2.49 bc	0.19	1.42 a
2x N in November	2.37 ab	0.16 abc	1.29	2.22 a	0.18 a	1.35 a	2.56 abc	0.19	1.32 b
2x NPK in November	2.35 ab	0.15 bc	1.19	2.03 b	0.16 ab	1.22 c	2.58 abc	0.18	1.29 b
2x N in April	2.34 ab	0.15 bc	1.22	2.20 a	0.17 ab	1.24 bc	2.59 abc	0.18	1.27 b
2x NPK in April	2.45 a	0.15 abc	1.24	2.25 a	0.17 ab	1.22 c	2.60 ab	0.19	1.33 ab
BMP N (Control) (1x N in July, Aug., Nov. + Apr.)	2.38 ab	0.16 ab	1.26	2.25 a	0.17 ab	1.24 bc	2.64 a	0.19	1.26 b
BMP NPK (1x NPK in July, Aug., Nov. + Apr.)	2.33 b	0.14 c	1.26	2.17 ab	0.16 ab	1.20 c	2.48 bc	0.18	1.35 ab
P-value	0.0417	0.0339	0.4861	0.0282	0.1078	0.0107	0.0891	0.4900	0.0146

[z] Means in a vertical column followed by a different letter are significantly different at $P = 0.05$ by Duncan's Multiple Range Test.

Table 3. Effect of soil-applied N or NPK fertilizer on 3-year average leaf total N, P and K (expressed as % dry wt.) of the 'Hass' avocado harvested in 2004, 2005 and 2006.

	N	P	K
Treatment			
1x N in July +August	2.30 b[z]	0.16 cd	1.25 c
1x NPK in July + August	2.31 b	0.17 ab	1.35 a
2x N in November	2.38 ab	0.17 ab	1.32 ab
2x NPK in November	2.32 b	0.16 bcd	1.23 c
2x N in April	2.38 ab	0.17 abcd	1.24 c
2x NPK in April	2.43 a	0.17 abc	1.26 bc
BMP N (Control) (1x N in July, Aug., Nov. + Apr.)	2.42 a	0.17 a	1.25 bc
BMP NPK (1x NPK in July, Aug., Nov. + Apr.)	2.33 b	0.16 d	1.27 bc
Year			
2004	2.35 b	0.15 c	1.25 b
2005	2.17 c	0.17 b	1.25 b
2006	2.55 a	0.19 a	1.31 a
P-value			
Treatment (T)	0.0029	0.0246	0.0113
Year (Y)	<0.0001	<0.0001	<0.0001
T x Y	0.2131	0.7524	0.2730

[z] Means in a vertical column followed by a different letter are significantly different at $P = 0.05$ by Duncan's Multiple Range Test.

Table 4. Effect of N versus N, P and K fertilization strategies on the 3-year average yield and fruit size of 'Hass' avocado harvested in 2004, 2005 and 2006.

	Total yield	Yield of small and large fruit based on packing carton sizes[z]						
		84	70	Σ84-70	60	48	40	Σ60-40
	kg fruit/tree							
Treatment								
1x N in July +August	39.11 abc[y]	2.48	9.32 abc	11.79 ab	10.16 abc	12.44	4.28	26.87 ab
1x NPK in July + August	46.23 a	2.77	12.31 ab	15.08 ab	12.58 a	12.27	4.36	29.22 a
2x N in November	36.24 bc	1.08	7.43 bc	8.51 b	10.72 abc	11.82	4.13	26.67 ab
2x NPK in November	33.00 c	1.89	7.23 c	9.12 b	8.87 bc	10.25	2.99	22.11 b
2x N in April	42.57 ab	2.87	8.87 abc	11.74 ab	12.27 ab	13.62	4.17	30.06 a
2x NPK in April	36.74 bc	2.34	8.16 bc	10.50 ab	10.21 abc	11.75	3.72	25.67 ab
BMP N (Control) (1x N in July, Aug., Nov. + Apr.)	45.07 ab	2.52	13.52 a	16.04 a	13.60 a	11.30	3.15	28.06 ab
BMP NPK (1x NPK in July, Aug., Nov. + Apr.)	32.28 c	1.72	8.44 bc	10.17 ab	8.50 c	10.10	3.01	21.62 b
Year								
2004	49.58 a	3.06 a	10.72 a	13.77 a	11.91	14.70 a	6.70 a	33.31 a
2005	33.29 b	0.40 b	4.61 b	5.01 b	10.35	14.04 a	3.55 b	27.95 a
2006	33.97 b	3.21 a	12.94 a	16.14 a	10.38	6.41 b	0.96 c	17.76 b
P-value								
Treatment (T)	0.0020	0.6343	0.0221	0.0866	0.0133	0.3228	0.3972	0.0223
Year (Y)	0.0005	<0.0001	<0.0001	<0.0001	0.5946	<0.0001	<0.0001	<0.0001
T x Y	0.0624	0.8580	0.5486	0.6964	0.0385	0.0143	0.6663	0.0143

[z] Packing carton fruit sizes include 84 (94-134 g), 70 (135-177 g), 60 (178-212 g), 48 (213-269 g) and 40 (270-325 g).

[y] Means in a vertical column followed by a different letter are significantly different at $P = 0.05$ by Duncan's Multiple Range Test.

Table 5. Effect of N versus N, P and K fertilization strategies on the 3-year average yield and fruit size of ‘Hass’ avocado harvested in 2004, 2005 and 2006.

		Yield of small and large fruit based on packing carton sizes[z]						
	Total yield	84	70	Σ84-70	60	48	40	Σ60-40
	No. fruit/tree							
Treatment								
1x N in July +August	200 ab[y]	21	60 abc	81	52 abc	52	14	118 abc
1x NPK in July + August	235 a	24	79 ab	103	65 a	51	15	130 a
2x N in November	178 b	9	48 bc	57	55 abc	49	14	118 abc
2x NPK in November	163 b	16	46 c	63	45 bc	43	10	98 bc
2x N in April	217 ab	25	57 abc	82	63 ab	57	14	133 a
2x NPK in April	188 ab	20	52 bc	72	52 abc	49	13	114 abc
BMP N (Control) (1x N in July, Aug., Nov. + Apr.)	238 a	22	87 a	108	70 a	47	11	127 ab
BMP NPK (1x NPK in July, Aug., Nov. + Apr.)	166 b	15	54 bc	69	44 c	42	10	96 c
Year								
2004	245 a	26 a	69 a	95 a	61	61 a	23 a	145 a
2005	157 b	3 b	30 b	33 b	53	58 a	12 b	123 a
2006	194 ab	28 a	83 a	110 a	53	27 b	3 c	83 b
P-value								
Treatment (T)	0.0060	0.6343	0.0221	0.1172	0.0133	0.3228	0.3972	0.0170
Year (Y)	0.0041	<0.0001	<0.0001	<0.0001	0.5946	<0.0001	<0.0001	<0.0001
T x Y	0.1513	0.8580	0.5486	0.7269	0.0385	0.0143	0.6663	0.0137

[z] Packing carton fruit sizes include 84 (94-134 g), 70 (135-177 g), 60 (178-212 g), 48 (213-269 g) and 40 (270-325 g).

[y] Means in a vertical column followed by a different letter are significantly different at $P = 0.05$ by Duncan’s Multiple Range Test.

Table 6. Effect of N versus N, P and K fertilization strategies on the 3-year cumulative yield and fruit size of 'Hass' avocado harvested in 2004, 2005 and 2006.

Treatment	Total yield	Yield of small and large fruit based on packing carton sizes[z]						
		84	70	Σ84-70	60	48	40	Σ60-40
	kg fruit/tree							
1x N in July +August	115.78 abc[y]	7.02	26.57 ab	33.60	28.81 ab	37.20	14.33	80.33 abc
1x NPK in July + August	138.58 a	7.86	35.14 a	43.00	37.83 a	39.26	15.60	92.68 a
2x N in November	108.61 bc	3.21	20.56 b	23.77	29.65 ab	36.46	14.78	80.88 abc
2x NPK in November	99.10 c	4.84	21.28 b	26.12	27.26 ab	32.21	10.58	70.05 bc
2x N in April	127.55 ab	7.96	25.68 ab	33.64	34.32 ab	41.67	15.09	91.08 a
2x NPK in April	110.16 bc	6.52	22.81 ab	29.33	29.55 ab	36.20	13.19	78.93 abc
BMP N (Control) (1x N in July, Aug., Nov. + Apr.)	133.26 ab	6.18	33.31 ab	39.48	37.50 a	37.87	14.09	89.47 ab
BMP NPK (1x NPK in July, Aug., Nov. + Apr.)	96.68 c	5.11	24.65 ab	29.76	25.66 b	30.11	9.63	65.40 c
P-value	0.0035	0.5359	0.0969	0.1854	0.0661	0.1586	0.3758	0.0109

[z] Packing carton fruit sizes include 84 (94-134 g), 70 (135-177 g), 60 (178-212 g), 48 (213-269 g) and 40 (270-325 g).

[y] Means in a vertical column followed by a different letter are significantly different at $P = 0.05$ by Duncan's Multiple Range Test.

Table 7. Effect of N versus N, P and K fertilization strategies on the 3-year cumulative yield and fruit size of ‘Hass’ avocado harvested in 2004, 2005 and 2006.

Treatment	Total yield	Yield of small and large fruit based on packing carton sizes[z] 84	70	Σ84-70	60	48	40	Σ60-40
	No. fruit/tree							
1x N in July +August	586 abc[y]	60	170 ab	231	148 ab	154	48	350 ab
1x NPK in July + August	710 a	67	225 a	293	194 a	163	52	409 a
2x N in November	524 bc	28	132 b	159	152 ab	151	50	353 ab
2x NPK in November	493 c	42	136 b	178	140 ab	134	36	309 b
2x N in April	641 abc	68	165 ab	233	176 ab	173	51	400 a
2x NPK in April	554 abc	56	146 ab	202	152 ab	150	44	346 ab
BMP N (Control) (1x N in July, Aug., Nov. + Apr.)	676 ab	53	214 ab	267	192 a	157	47	397 a
BMP NPK (1x NPK in July, Aug., Nov. + Apr.)	495 c	44	158 ab	202	132 b	125	32	289 b
P-value	0.0111	0.5359	0.0969	0.2142	0.0661	0.1586	0.3758	0.0105

[z] Packing carton fruit sizes include 84 (94-134 g), 70 (135-177 g), 60 (178-212 g), 48 (213-269 g) and 40 (270-325 g).

[y] Means in a vertical column followed by a different letter are significantly different at $P = 0.05$ by Duncan’s Multiple Range Test.

Table 8. Effect of N versus N, P and K fertilization strategies on 3-year average fruit quality of the 'Hass' avocado harvested in 2004, 2005 and 2006.

	Days to ripen	Flesh quality[z]		
		Vascularization	Discoloration	Decay
Treatment				
1x N in July +August	10.4	0.4 ab[y]	0.60	0.30
1x NPK in July + August	9.8	0.3 b	0.60	0.30
2x N in November	10.0	0.5 a	0.70	0.40
2x NPK in November	10.2	0.3 ab	0.70	0.30
2x N in April	10.2	0.4 ab	0.50	0.30
2x NPK in April	9.4	0.3 b	0.50	0.20
BMP N (Control) (1x N in July, Aug., Nov. + Apr.)	10.2	0.4 ab	0.60	0.20
BMP NPK (1x NPK in July, Aug., Nov. + Apr.)	10.0	0.3 ab	0.50	0.30
Year				
2004	9.3 b	0.2 c	0.3 c	0.1 c
2005	10.4 a	0.3 b	0.9 a	0.5 a
2006	10.3 a	0.5 a	0.6 b	0.3 b
P-value				
Treatment (T)	0.2949	0.0405	0.5376	0.5915
Year (Y)	<0.0001	<0.0001	<0.0001	<0.0001
T x Y	0.3373	0.2257	0.7116	0.5253

[z] When ripe, internal fruit quality was evaluated for abnormalities and discoloration. Vascularization (presence of vascular bundles and associated fibers) of the flesh was also determined. The internal fruit quality parameters were visually rated on a scale from 0 (normal) to 4 (high incidence of abnormalities, discoloration, or vascularization).

[y] Means in a vertical column followed by a different letter are significantly different at $P = 0.05$ by Duncan's Multiple Range Test.

Table 9. Effect of N versus N, P and K fertilization strategies on the alternate bearing index of ‘Hass’ avocado harvested in 2004, 2005 and 2006.

	Alternate bearing index		
Treatment	2004-2005	2005-2006	2-year average
1x N in July +August	0.60	0.63	0.61
1x NPK in July + August	0.66	0.66	0.66
2x N in November	0.58	0.70	0.64
2x NPK in November	0.61	0.64	0.60
2x N in April	0.59	0.70	0.65
2x NPK in April	0.55	0.68	0.61
BMP N (Control) (1x N in July, Aug., Nov. + Apr.)	0.59	0.66	0.63
BMP NPK (1x NPK in July, Aug., Nov. + Apr.)	0.54	0.62	0.60
P-value	0.9286	0.9927	0.9922

Table 10. Effect of N versus N, P and K fertilization strategies on the estimated 3-year cumulative return (dollars per kilogram) from yield of 'Hass' avocado harvested in 2004, 2005 and 2006.

		Return from small and large fruit based on packing carton sizes[z]						
Treatment	Total income	84	70	Σ84-70	60	48	40	Σ60-40
	$/kg fruit per tree							
1x N in July +August	588.19	28.017	120.11 ab[y]	148.13	157.18	211.95	64.90	434.02
1x NPK in July + August	604.88	27.811	135.67 a	163.48	170.17	192.62	68.46	431.25
2x N in November	514.69	12.242	88.52 b	100.76	157.06	183.29	61.91	402.26
2x NPK in November	520.18	19.468	97.75 ab	117.22	159.31	189.00	47.88	396.19
2x N in April	558.61	26.037	98.55 ab	124.58	162.26	205.57	58.24	426.07
2x NPK in April	570.00	27.588	104.55 ab	132.14	168.25	205.45	58.13	431.83
BMP N (Control) (1x N in July, Aug., Nov. + Apr.)	580.58	23.848	134.23 a	158.08	178.12	181.42	52.17	411.71
BMP NPK (1x NPK in July, Aug., Nov. + Apr.)	508.27	18.945	103.49 ab	122.43	149.86	183.34	46.79	379.99
P-value	0.2097	0.5492	0.0475	0.1268	0.7632	0.9179	0.7358	0.8171

[z] Packing carton fruit sizes include 84 (94-134 g), 70 (135-177 g), 60 (178-212 g), 48 (213-269 g) and 40 (270-325 g). The dollar value per pound fruit in each size class for each harvest came from the AvoGreensheet for Sept. 21, 2004 (vol. 20, issue 23), Sept. 20, 2005 (vol. 21, issue 24) and the average values in the Aug. 22, 2006 (vol. 22, issue 22) and Oct. 17, 2006 (vol.22, issue 26), respectively.

[y] Means in a vertical column followed by a different letter are significantly different at $P = 0.05$ by Duncan's Multiple Range Test.